US009109435B2

(12) **United States Patent**
O'Connor et al.

(10) **Patent No.: US 9,109,435 B2**
(45) **Date of Patent: Aug. 18, 2015**

(54) **MONOBORE EXPANSION SYSTEM—ANCHORED LINER**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 972 days.

(21) Appl. No.: **13/277,959**

(22) Filed: **Oct. 20, 2011**

(65) **Prior Publication Data**

US 2013/0098634 A1 Apr. 25, 2013

(51) **Int. Cl.**
E21B 43/10 (2006.01)

(52) **U.S. Cl.**
CPC ***E21B 43/103*** (2013.01); ***E21B 43/105*** (2013.01)

(58) **Field of Classification Search**
CPC E21B 43/103; E21B 43/105
See application file for complete search history.

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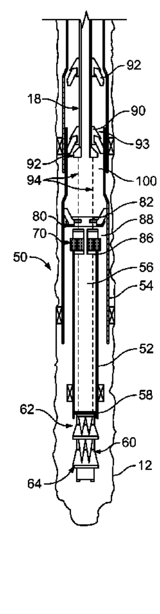
(57) **ABSTRACT**

Methods for forming a wellbore may include placing an upper section of inside a lower section of a parent liner; positioning an upper sealing member and a lower sealing member in the wellbore to form a pressure chamber, and expanding the second liner using the pressure chamber. The sealing members move axially relative to one another and the second liner has an inner bore that is hydraulically isolated from the pressure chamber. A related apparatus may include upper and lower sealing members that cooperate to form a pressure chamber that is hydraulically isolated from an inner bore of the second liner. A work string may include the sealing members, a connector that extends through the pressure chamber and the second liner; and an expander. The expander expands the second liner in response to the axial separation of the sealing members.

20 Claims, 8 Drawing Sheets



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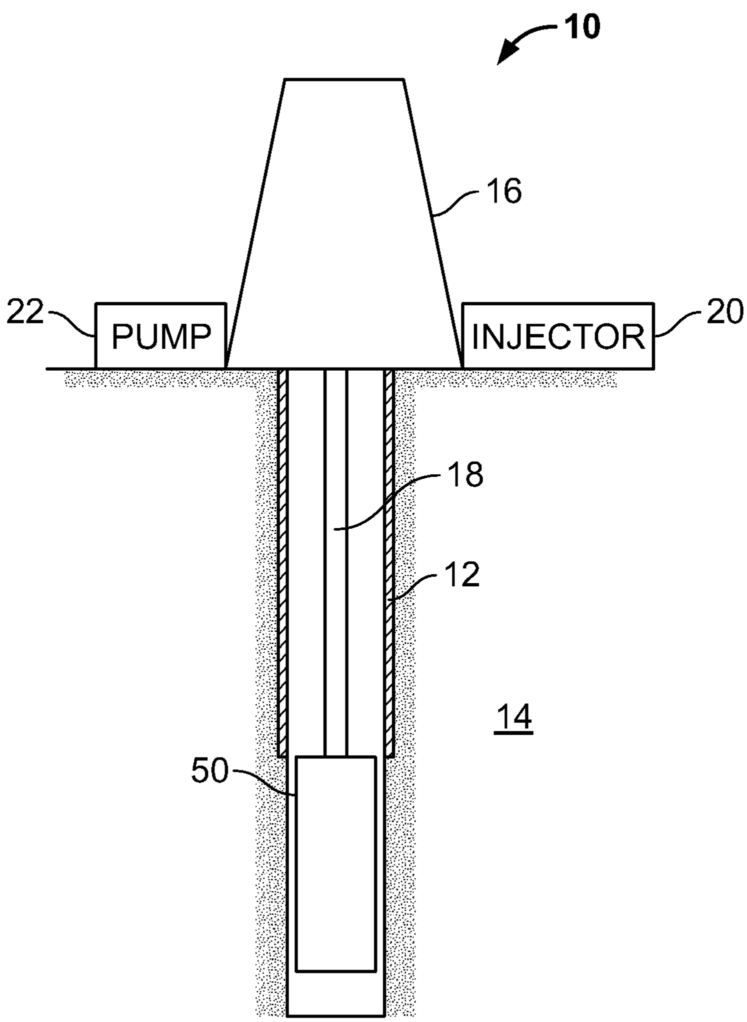

FIG. 1

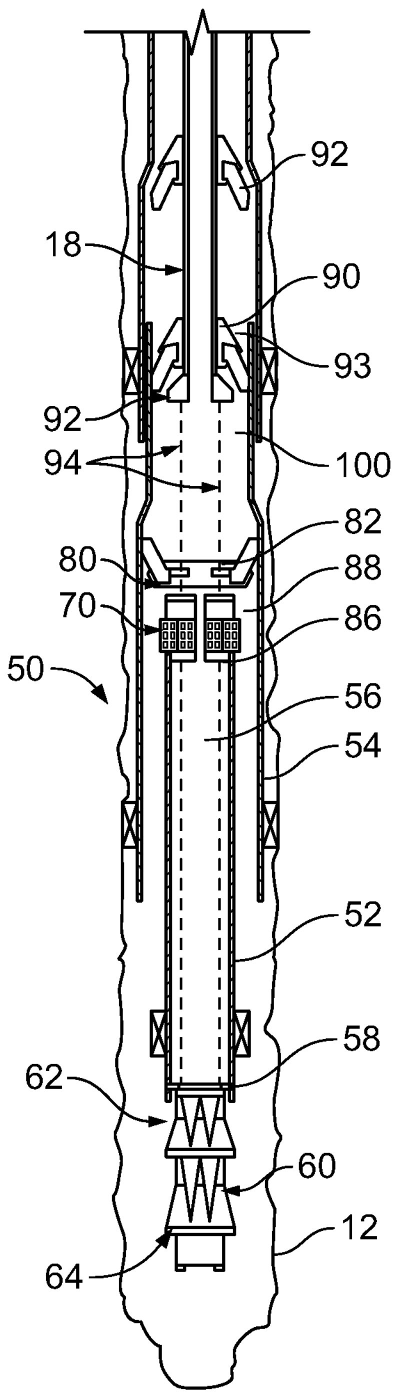

FIG. 2

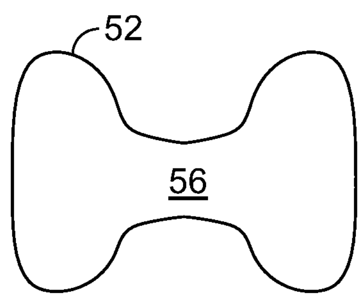

FIG. 3

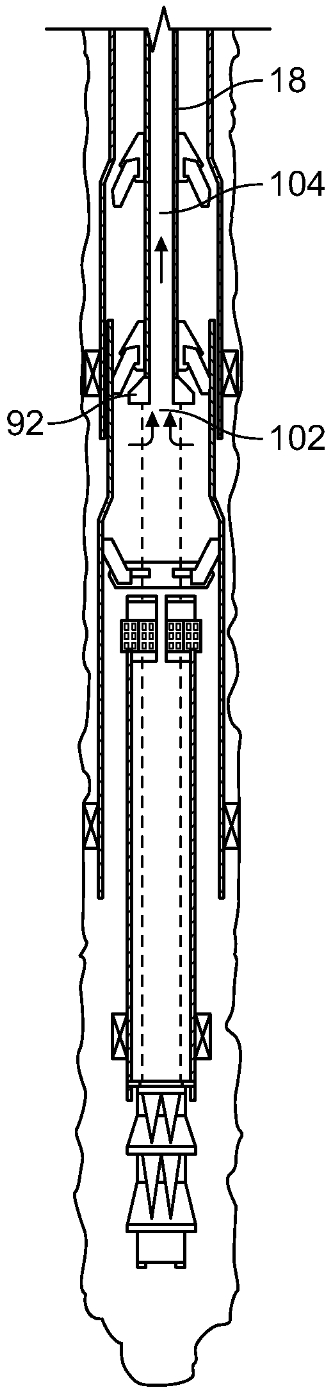

FIG. 4

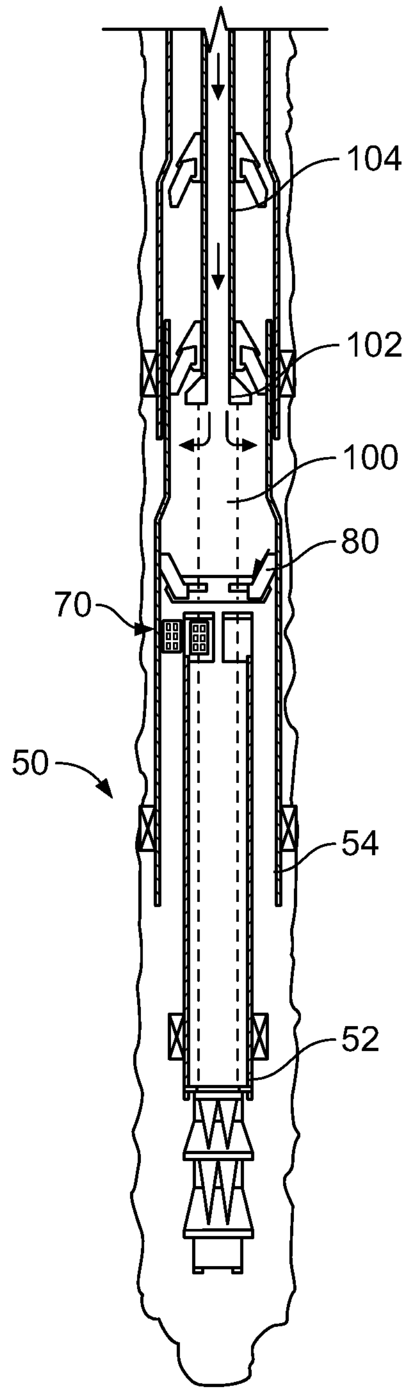

FIG. 5

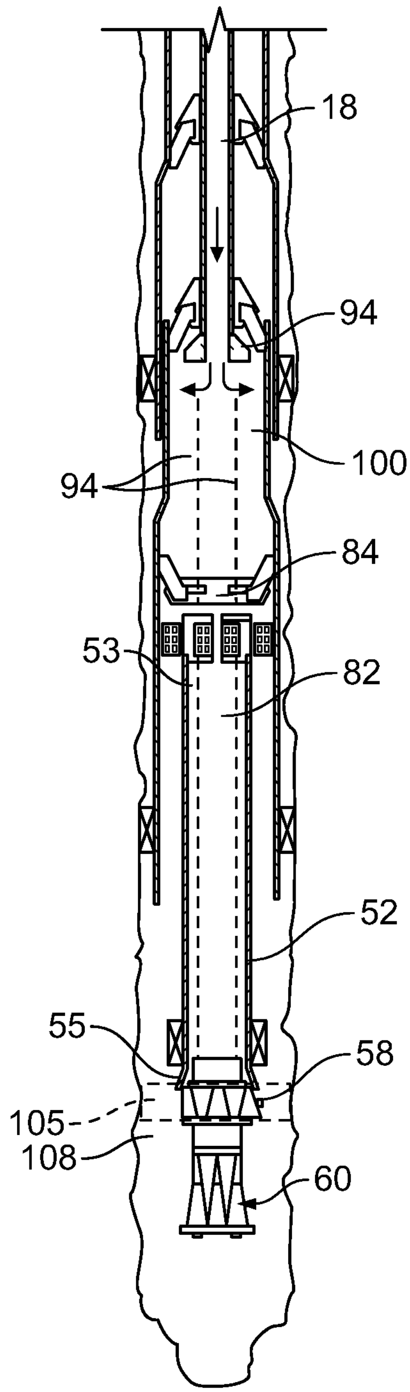

FIG. 6

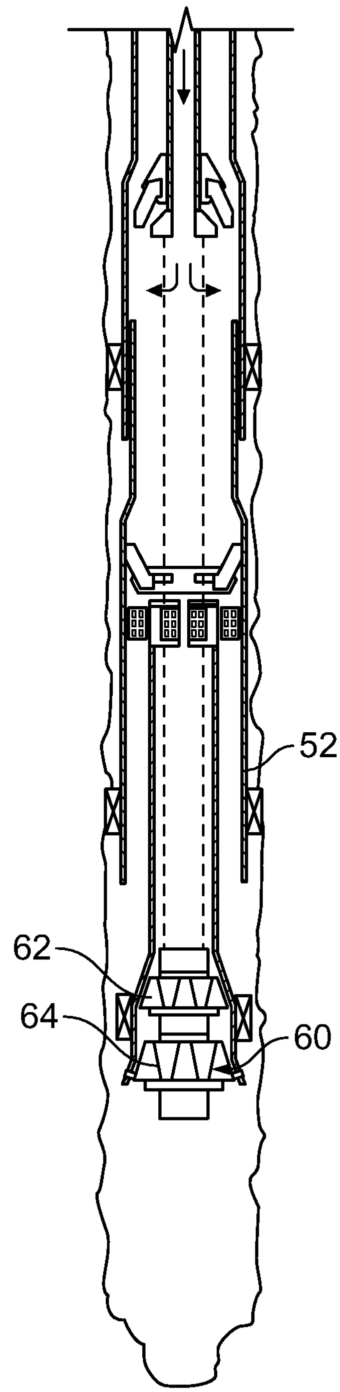

FIG. 7

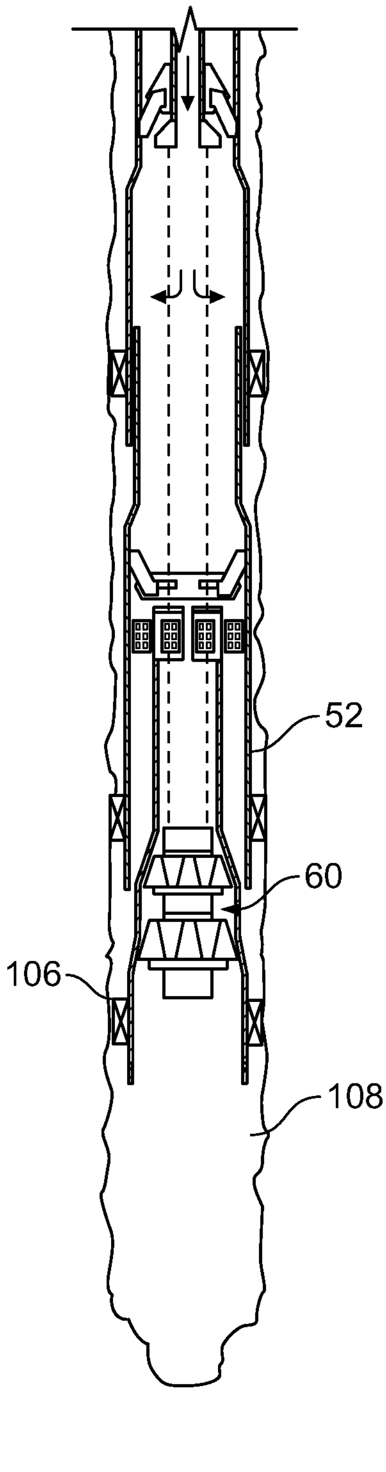

FIG. 8

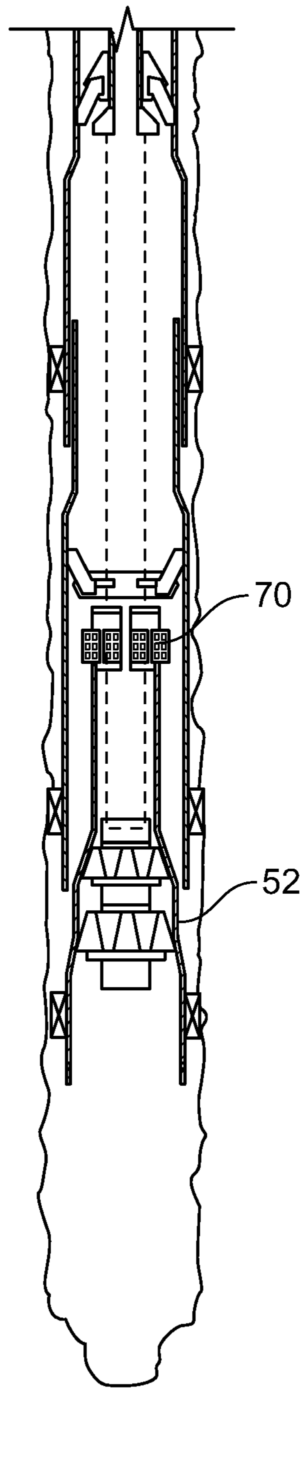

FIG. 9

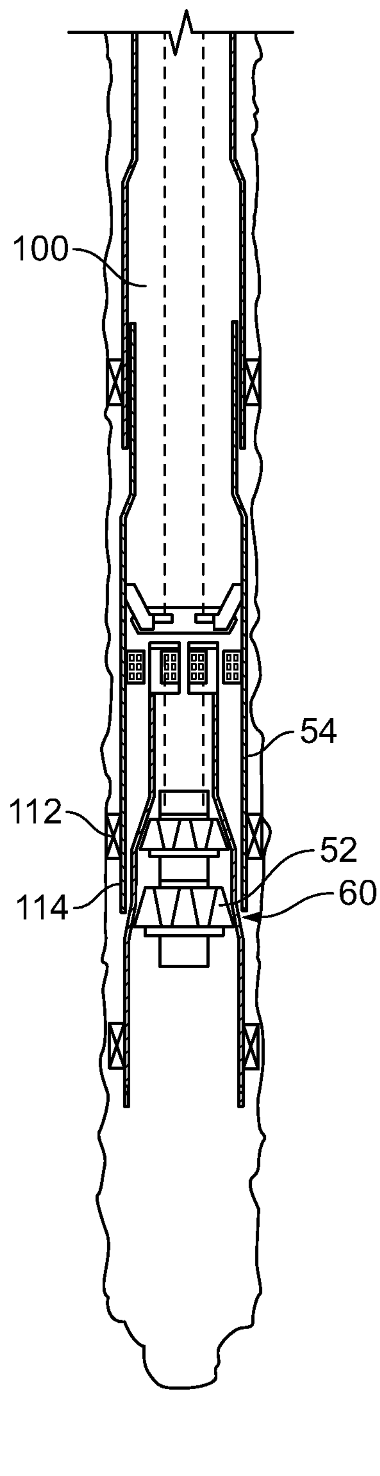

FIG. 10

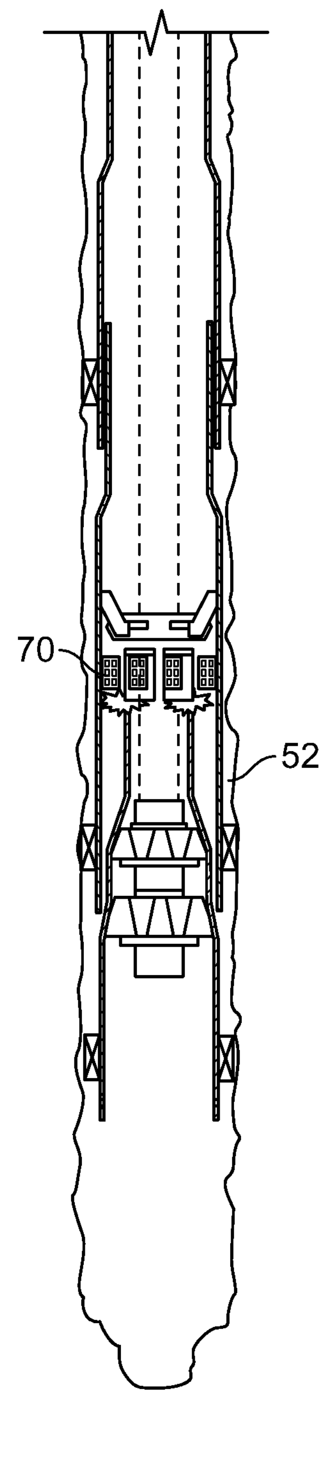

FIG. 11

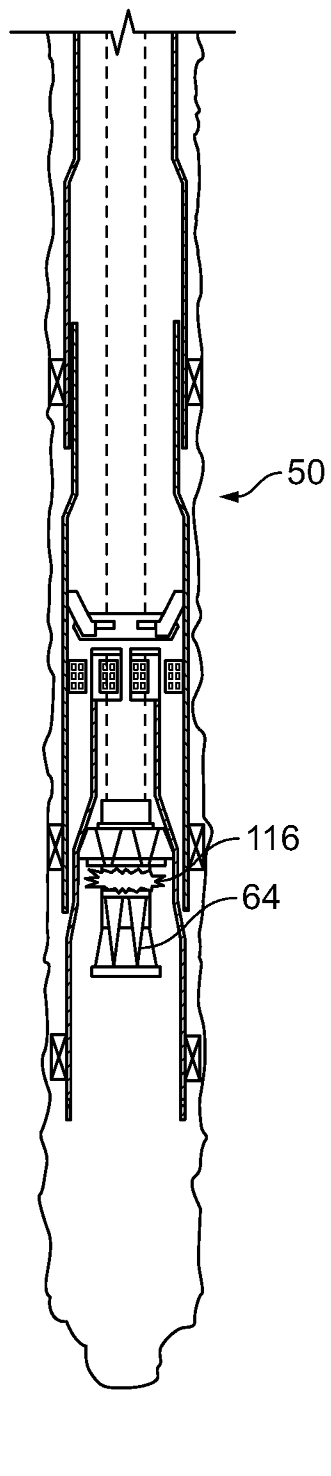

FIG. 12

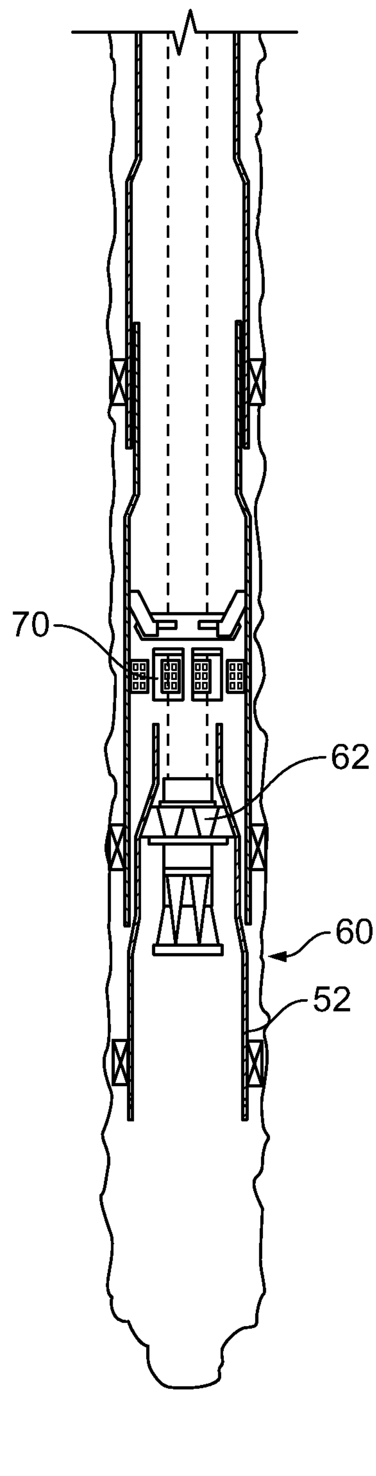

FIG. 13

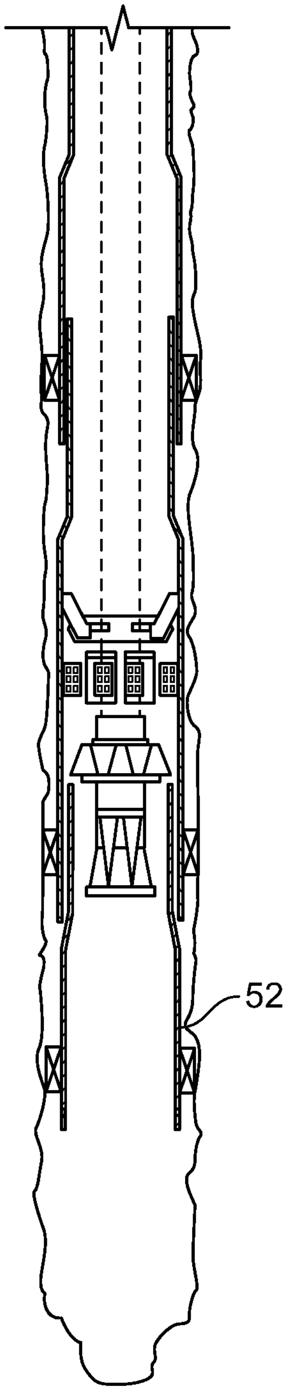

FIG. 14

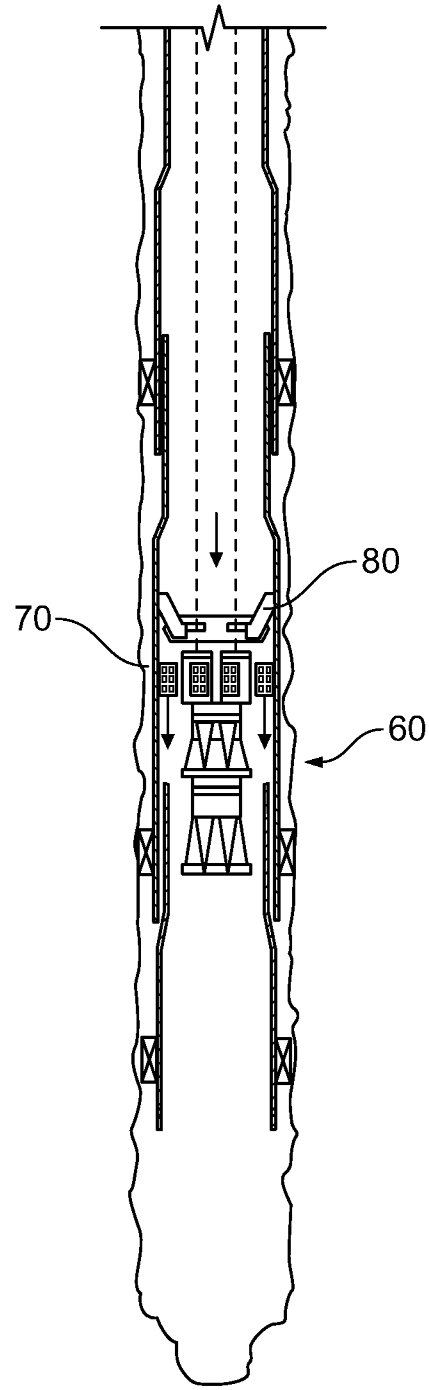

FIG. 15

MONOBORE EXPANSION SYSTEM—ANCHORED LINER

BACKGROUND OF THE DISCLOSURE

1. Field of the Disclosure

This disclosure relates generally to oilfield downhole tools and more particularly to assemblies utilized for completing wellbores.

2. Description of the Related Art

Hydrocarbons, such as oil and gas, as well as geothermal resources are recovered from a subterranean formation using a wellbore drilled into the formation. Such wellbores are typically completed by placing a casing along the wellbore length, cementing the annulus between the casing and the wellbore and perforating the casing adjacent each production zone. A wellbore casing is often made by joining relatively short pipe sections (for example 10 m long) via threaded connections at the pipe ends. Such conventional casing techniques utilize tubular strings of decreasing diameters and include multiple threaded connections. Monobore wellbore construction utilizing a solid casing design has limitations in terms of achievable collapse resistance of an expanded tubular. Expansion of liner elements connected with threads run a risk with respect to the achievable long term reliability. The cost of building deep and extended reach wells is very high. Therefore, it is desirable to provide alternative methods of building such wellbores.

SUMMARY OF THE DISCLOSURE

In aspects, the present disclosure provides a method of forming a wellbore. The method may include placing a first liner having a lower section in the wellbore; placing a second liner in the wellbore, with an upper section of the second liner placed inside the lower section of the first liner; positioning an upper sealing member and a lower sealing member in the wellbore to form a pressure chamber, the upper and lower sealing members being axially movable relative to one another; and expanding the second liner using the pressure chamber, the second liner having an inner bore hydraulically isolated from the pressure chamber.

In aspects, the present disclosure also provides an apparatus for positioning a first liner and a second liner in a wellbore. The second liner may have an upper section placed inside a lower section of the first liner. The apparatus may include at least one lower sealing member cooperating with at least one upper sealing member to form a pressure chamber that is hydraulically isolated from an inner bore of the second liner. The upper sealing member(s) and the lower sealing member (s) axially separate in response to a pressure in the pressure chamber. The apparatus may further include a work string that conveys the sealing members into the wellbore; at least one connector connected to the work string and extending through the pressure chamber and the second liner; and an expander connected to the connector. The expander expands the second liner in response to the axial separation of the sealing members.

BRIEF DESCRIPTION OF THE DRAWINGS

For detailed understanding of the present disclosure, references should be made to the following detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals and wherein:

FIG. **1** illustrates a rig for completing a well using a liner system in accordance with one embodiment of the present disclosure;

FIG. **2** illustrates a liner system in accordance with one embodiment of the present disclosure positioned in the wellbore;

FIG. **3** illustrates a folded liner in accordance with one embodiment of the present disclosure;

FIG. **4** illustrates a liner system in accordance with one embodiment of the present disclosure being run into the wellbore;

FIG. **5** illustrates a pressure chamber in accordance with one embodiment of the present disclosure being activated by fluid pumped down from the surface;

FIG. **6** illustrates an expander in accordance with one embodiment of the present disclosure being pulled into a liner;

FIG. **7** illustrates the expander in accordance with one embodiment of the present disclosure expanding the liner;

FIG. **8** illustrates the expander in accordance with one embodiment of the present disclosure expanding a liner shoe into engagement with a wellbore wall;

FIG. **9** illustrates an anchor in accordance with one embodiment of the present disclosure being deactivated to reduce a tension in the expanded liner;

FIG. **10** illustrates the expander in accordance with one embodiment of the present disclosure entering an overlapping region of the liner and a parent liner;

FIG. **11** illustrates the anchor in accordance with one embodiment of the present disclosure being disconnected from the liner;

FIG. **12** illustrates the expander in accordance with one embodiment of the present disclosure being collapsed into a reduced diameter configuration;

FIG. **13** illustrates the expander in accordance with one embodiment of the present disclosure continuing to travel through and expand the liner;

FIG. **14** illustrates a fully expanded liner; and

FIG. **15** illustrates a bypass allowing fluid flow across the liner assembly while the liner assembly is conveyed out of the well.

DETAILED DESCRIPTION OF THE DISCLOSURE

The present disclosure relates to monobore wellbores using overlapping expandable liners to case the wellbore. The present disclosure is susceptible to embodiments of different forms. There are shown in the drawings, and herein will be described in detail, exemplary embodiments of the present disclosure with the understanding that the present disclosure is to be considered an exemplification of the principles of the disclosure and is not intended to limit the disclosure to that illustrated and described herein.

Referring initially to FIG. **1**, there is shown a system **10** for performing a wellbore-related operation such as completing a wellbore **12** drilled in a formation **14**. The system **10** includes a rig **16** at the surface for deploying a work string **18**. The work string **18** may convey a liner completion system **50** for lining the wellbore **12** with wellbore tubulars. The tubulars may be a liner, casing, coiled tubing, rigid tubulars, or other tubulars that are configured to be expanded and fixed in the wellbore **12**. The wellbore **12** may be for recovering, hydrocarbons, such as oil and gas, as well as for accessing geothermal resources. The rig **16** may include devices such as an injector **20** to convey the work string **18** into and out of the wellbore **12** and a pump **22**. It should be understood that the injector **20** and pump **22** are merely illustrative of the types of equipment that may be used in connection with wellbore operations described below.

Referring now to FIG. **2**, there is shown one embodiment of a liner system **50** that may be used to connect a liner **52** to a parent liner **54**. The liner system **50** may include an expander **60** for expanding the liner **52**, an anchor **70** that selectively anchors the liner **52** to the parent liner **54**, and a lower sealing member **80** and an upper sealing member **90** that form a pressure chamber **100** external to the liner **52**. The upper and lower sealing members **80**, **90** are both positioned in the wellbore **12** as opposed to at the surface (which may be a seabed). Thus, unlike surface or seabed equipment such as wellheads, subsea wellheads, risers, and blowout preventers, the sealing members **80**, **90** are dimensioned and shaped to be conveyed along the wellbore **12** using the work string **18**.

Referring now to FIG. **3**, the liner **52** may be formed as an expandable tubular having a dipole folded geometry. The liner **52** may have a non-circular non-expanded geometry that has a smaller effective diameter than when the liner **52** has been fully expanded. The liner **52** may be expanded by pulling the expander **60** (FIG. **2**) through the passage **56**. In one embodiment, the liner **52** is unfolded from an initial non-circular shape to an intermediate circular shape and then expanded to a circular shape of a larger diameter. In another embodiment, the liner **52** has an initial circular shape and is expanded to a greater diameter.

The work string **18** may be configured to pull the expander **60** through the passage **56**. In one embodiment, the work string **18** may include a coupling **92** that connects one or more connectors **94** to the expander **60**. For convenience, coiled tubing will be used as an exemplary work string, but it should be understood that any rigid or non-rigid member may be also used as a work string.

The connectors **94** may be bars, tubes, rods or other similar elongated members that connect the expander **60** to the work string **18**. The connectors **94** may be configured to reside within the passage **56** and to transmit at least tension forces in the work string **18** to the expander **60**. The connectors **94** may be rigid (e.g., steel rods) or non-rigid (e.g., steel cables). While two connectors **94** are shown, it should be understood that greater or fewer number of connector members may be used.

The upper sealing member **90** may be attached to the work string **18** and configured to selectively form a fluid barrier across an annular space **93** between the work string **18** and an inner diameter of the parent liner(s) **54**. While two upper sealing members **90** are shown, it should be understood that fewer or greater number of sealing members may be serially distributed along the work string **18**.

The lower sealing member **80** selectively forms a fluid barrier that prevents fluid pressure in the bore **82** from increasing fluid pressure inside the liner **52**. Thus, the lower sealing member **80** hydraulically isolates the interior of the liner **52** from pressure uphole of the lower sealing member **80**. The lower sealing member **80** may include one or more dynamic seals **84** that allow the connector(s) **94** to slide axially while maintain a sealing barrier across the bore **82**. In some embodiments, the dynamic seals **84** may be structurally and functionally independent of the lower sealing member **80**. The lower sealing member **80** may further include a port **86** that allows fluid communication between a bore **56** of the liner **52** and the annular space **88**.

The sealing members **80**, **90** may include a cup-shaped pliable sealing element that has direction-sensitive sealing functionality (e.g., swab cups). That is, the sealing elements may be canted to allow a seal to form when pressure is increased in either downhole or uphole location. In one arrangement, the upper sealing member **92** may have sealing element canted downward so that a downhole pressure increase activates the sealing function. The lower sealing member **92** may have sealing element canted upward so that an uphole pressure increase activates the sealing function. Thus, the opposing canted sealing elements of the sealing members **80**, **90** cooperate to form a sealed environment for the pressure chamber **100**, which is between the sealing members **80**, **90**.

In such arrangements, the upper sealing member **92** is deactivated when conveyed uphole and the lower sealing member **92** is deactivated when conveyed downhole. By deactivated, it is meant that fluid flow is permitted across the sealing members **80**, **90**. As discussed below, bypasses and valves may be used to reduce surge and/or swab effects when the upper sealing member **92** is conveyed downhole and the lower sealing member **92** is conveyed uphole.

The anchor **70** is fixed to an upper end of the liner **52** and selectively connects the liner **52** to the parent liner **54**. As discussed above, the sealing members **80**, **90** form fluid tight barriers that define a pressure chamber **100**. When the pressure in the pressure chamber **100** reaches a predetermined value, the anchor **70** extends into an anchoring engagement with the liner **54**. The pressure chamber **100** may be pressurized using fluids pumped from the surface by a pump **22** (FIG. **1**) via the work string **18**. Thus, the anchor **70** is activated/actuated using a pressure in the pressure chamber **100**. Non-limiting devices suitable for the anchor **70** include radially extendable slips, pads, and arms.

The expander **60** may be a swage-type device that is coupled to a lower end of the connectors **94** and has a diameter or diameters selected to expand the liner **52** to a desired diameter. In one embodiment, the expander **60** may include an upper cone **62** and a lower cone **64**. The cones **62**, **64** may be formed of rigid materials. A locking member **58** may be used to connect the expander **60** to a lower end of the liner **52**. The locking member **58** may be a shear pin or other device that is calibrated to decouple the expander **60** from the liner **52** upon a preset condition (e.g., a selected tension force). Also, one or both of the cones **62**, **64** may be collapsible. That is, in an umbrella-type of fashion, the cones **62**, **64** may be fixed in an enlarged configuration during the expansion process. Thereafter, a device such as a shear pin or locking mechanism may be activated (e.g., snapped or broken) to allow the cones **62**, **64** to collapse into a dimensionally smaller configuration.

Referring now to FIGS. **4-15**, the use of the liner system **50** to line a wellbore **12** will be described. In FIG. **4**, the system **50** is being shown after being "run in" the wellbore **12**. Typically, the wellbore **12** is filled with liquids. Therefore, the fluids below the liner system **50** may encounter a surge as the liner system **50** traverses the wellbore **12**. Since the lower sealing member **80** is being conveyed downhole, the sealing function is deactivated due to the upwardly canted sealing member. Thus, fluids downhole of the liner system **50** flow to the opening **102** and to a bore **104** of the work string **18** at the coupling **92** and thereby reduce surge effects.

Referring now to FIG. **5**, the liner system **50** is shown positioned at a distal end of the parent liner **54**. Fluid pumped downhole via the bore **104** exits at the opening **102** and flows into the pressure chamber **100**. Once the pressure in the pressure chamber **100** reaches a preset value, the lower sealing member **80** moves and engages the anchor **70**. In response, the anchor **70** expands and anchors the liner **52** with the parent liner **54**. It should be understood that other activation arrangements using a pressure in the pressure chamber

100 may be used to energize and activate the anchor **70**. For example, the pressure in the pressure chamber **100** may be used by a piston cylinder system to engage ramps or sliding elements that drive anchoring elements of the anchor **52** radially outward into engagement with the parent liner **54**.

Referring now to FIG. **6**, as more fluid is pumped into the pressure chamber **100**, the increased pressure applied to the upper sealing member **90** drives the work string **18** in an uphole direction. Thus, the upper and lower sealing members **90**, **80** axially separate because the lower sealing member **80** is stationary and the upper sealing member **90** moves uphole. Because the expander **60** is fixedly connected to the work string **18** by the connectors **94**, the expander **60** is also pulled in the uphole direction and into the liner **52**. Once the tension force is sufficient to fracture or break the locking member **68**, the expander **60** enters and expands the liner **52**. In embodiments where the expander **60** includes a first cone **62** and a second cone **64**, the first cone **62** may expand the liner **52** to a first diameter and the second cone **64** may expand the liner **52** to a larger second diameter.

The axial travel of the expander **60** through the liner **52** may induce axial loading on the liner **52**. These loadings may be controlled by selectively anchoring the upper end **53** and the lower end **55** of the liner **52** during expansion. As shown in FIG. **6**, the lower end **55** is not anchored to the wellbore wall **108** and the upper end **53** is anchored to the parent liner **54**. Thus, upward axial travel of the expander **60** may cause a compressive loading in the liner **52**, which may lead to buckling. In one variant, the lower end **53** of the liner **52** may be anchored to the wellbore wall **108** before the expander **60** using a suitable anchor **105**. The anchor **105** may be any device that includes pads, ribs, slips, spikes, or other suitable anchoring elements that extend radially outward and engage the wellbore wall **108**. The driver or actuator (not shown) for driving the anchoring elements into the wellbore wall **108** may be energized by pressurized fluids, electrical power, any other power source, which may be positioned at the surface or downhole. The anchor **105** takes up the axial loading during expansion and thus reduces the likelihood of buckling. It should be appreciated that the liner **52** may be expanded while under compression or tension while the anchor **105** is activated. To expand the liner **52** under compression, the anchor **70** may activated and engaged as shown in FIG. **6**. To expand the liner **52** under tension, the anchor **70** may de-activated to release the upper end **53**. It should be understood, tension and compression may be present the liner **52** in either situation (e.g., during compression, the section of the liner **52** downhole of the anchor **70** may be in tension). Thus, the tension or compression as referred to above is a predominant condition, as opposed to the only condition.

Generally, during the expansion of the liner **52**, it should be appreciated that the pressure in the pressure chamber **100** is not communicated to the inner bore of the liner **52**. Rather the dynamic seals **84** maintain a sealing barrier across the bore **82** while the connector(s) **94** to slide or translate axially upward. The pressure isolation of the bore **82** is maintained throughout the expansion process.

Referring now to FIG. **7**, the first cone **62** and the second cone **64** of the expander **60** are shown travelling axially through the liner **52** and incrementally expanding the liner **52** to a first diameter, and then to a second larger diameter. Referring now to FIG. **8**, a liner shoe **106** of the liner **52** is shown expanded and sealed with a wellbore wall **108** by the expander **60**.

Referring now to FIG. **9**, there is shown a step that may be taken to reduce the tension in the liner **52**. Generally, expanding a diameter of the liner **52** will cause a reduction in the length of the liner **52**. During the FIG. **8** step, the liner **52** is fixed at both ends. Thus, the partially expanded liner **52** is in tension. To reduce the tension, the anchor **70** may be released, as shown, and thereafter reset.

In one variant, the liner **52** may be configured to be installed with a pre-tension value that is selected relative to a predicted expansion caused by applied in situ thermal energy. For instance, for geothermal wells, the liner **52** may be expected to lengthen due to thermal expansion. For such situations, the liner **52** may be expanded continuously and anchored into place. A suitable liner for such situations may include either an open hole packer at the expandable liner shoe or another anchoring device that anchors the liner shoe into the open hole. Therefore, the liner may be expanded in a fixed-fixed end condition that prevents axial shortening. With this arrangement, the pretension caused by expansion remains after the liner and parent liner are fixed in the wellbore. As the liner heats up to wellbore temperatures, the pretension is reduced to near neutral due to thermal expansion.

In conventional geothermal applications, casing is fully cemented to surface to fully support the casing and reduce the risk of compressive buckling during heat up. The fixed-fixed end variant described above may remove the need for a full cement sheath, and possibly the requirement for cement at all.

Referring now to FIG. **10**, the expander **60** is shown entering a region **112** where the liners **52**, **54** overlap. When the expander **60** reaches a shoe **114** of the parent liner **54**, the axial movement of the expander **60** is impeded. Because the pressure chamber **100** can no longer expand as fluid is pumped in, the pressure spikes. As shown in FIG. **11**, once the pressure increases in the pressure chamber **100** to a preset value, a decoupling device (not shown) activates and allows the anchor **70** to separate from the liner **52**. Suitable pressure-activated decoupling devices may be used to separate the anchor **70** from the liner **52**.

Referring now to FIG. **12**, a combination of increased pressure by pumping fluid and "overpull" (pulling up on the work string **18**) are applied to the liner assembly **50**. These tension forces activate a retraction device **116** in the expander **60** that allows the lower cone **64** to retract. For example, a shear pin (not shown) may be calibrated or configured to fracture and allow the lower cone **64** to collapse upon encountered a preset force (e.g., tension force).

Referring now to FIG. **13**, the upper cone **62** of the expander **60** continues to expand the liner **52**. It should be noted that the upper end of the liner **52** separates axially from the anchor **70** due to the shortening that occurs during expansion. FIG. **14** shows the liner **52** fully expanded.

Referring now to FIG. **15**, the expander **60** is shown engaging the anchor **70** and the lower sealing member **80**. This engagement activates a bypass (not shown) in the lower sealing member **80** that allows fluid communication across the lower sealing member **80**. Thus, when the liner system **50** is pulled out of the wellbore **12**, the fluid uphole of the lower sealing member **80** can flow across and downhole of the lower sealing member **80**.

The term "work string" as used herein means any device, device component, combination of devices, media and/or member that may be used to convey, house, support or otherwise facilitate the use of another device, device component, combination of devices, media and/or member. Exemplary non-limiting work strings include drill strings of the coiled tube type, of the jointed pipe type and any combination or portion thereof. Other carrier examples include casing pipes, downhole subs.

The foregoing description is directed to particular embodiments of the present disclosure for the purpose of illustration and explanation. It will be apparent, however, to one skilled in the art that many modifications and changes to the embodiment set forth above are possible without departing from the scope of the disclosure.

The invention claimed is:

1. A method of lining a wellbore, comprising:

placing a first liner in the wellbore, the first liner having a lower section;

placing a second liner in the wellbore, with an upper section of the second liner placed inside the lower section of the first liner;

positioning an upper sealing member and a lower sealing member in the wellbore to form a pressure chamber, wherein the upper sealing member and the lower sealing member move axially away from one another, the axial movement causing the work string to move upward and pull the expander through a bore of the second liner;

expanding the second liner using the pressure chamber; and

positioning the upper and the lower sealing members in the first liner and above the second liner, thereby hydraulically isolating an inner bore of the second liner from the pressure chamber.

2. The method of claim **1**, further comprising anchoring the second liner to the first liner using an anchor.

3. The method of claim **2**, further comprising activating the anchor using the pressure chamber.

4. The method of claim **1**, wherein the expanding is done using an expander connected via at least one connector to a work string.

5. The method of claim **4**, further comprising fixing the upper sealing member to the work string.

6. The method of claim **4**, further comprising forming a fluid seal using at least a dynamic seal to hydraulically isolate the inner bore of the second liner.

7. The method of claim **4**, further comprising conveying the upper sealing member and the lower sealing member into the wellbore using the work string.

8. The method of claim **4**, further comprising pumping a fluid down the work string to pressurize the pressure chamber.

9. The method of claim **1**, further comprising:

fixing the ends of the second liner during expansion to cause a selected pretension; and

fixing the second liner in the wellbore with the selected pretension.

10. A method of lining a wellbore, comprising:

placing a first liner in the wellbore, the first liner having a lower section;

placing a second liner in the wellbore, with an upper section of the second liner placed inside the lower section of the first liner;

positioning an upper sealing member and a lower sealing member in the wellbore to form a pressure chamber;

pumping a fluid down the work string to pressurize the pressure chamber; and

expanding the second liner using the pressure chamber, wherein the upper sealing member and the lower sealing member move axially away from one another, the axial movement causing the work string to move upward and pull the expander through a bore of the second liner, and wherein the expanding is done using an expander connected via at least one connector to a work string.

11. The method of claim **10**, further comprising anchoring the second liner to the first liner using an anchor, and activating the anchor using the pressure chamber.

12. The method of claim **10**, further comprising fixing the upper sealing member to the work string.

13. The method of claim **10**, further comprising forming a fluid seal using at least a dynamic seal to hydraulically isolate the inner bore of the second liner.

14. An apparatus for positioning a first liner and a second liner in a wellbore, the second liner having an upper section placed inside a lower section of the first liner, the apparatus comprising:

at least one upper sealing member;

at least one lower sealing member cooperating with the at least one upper sealing member to form a pressure chamber that is hydraulically isolated from an inner bore of the second liner, wherein the at least one upper sealing member and the at least one lower sealing member are positioned in the first liner and above the second liner, and wherein the at least one upper sealing member and the at least one lower sealing member are configured to axially separate in response to a pressure in the pressure chamber;

a work string configured to convey the at least one upper sealing member and the at least one lower sealing member into the wellbore, and wherein the axial separation causes the work string to move upward and pull the expander through a bore of the second liner;

at least one connector connected to the work string and extending through the pressure chamber and the second liner; and

an expander connected to the connector, the expander being configured to expand the second liner in response to the axial separation of the at least one upper sealing member and the at least one lower sealing member.

15. The apparatus of claim **14**, further comprising an anchor configured to selectively anchor the second liner to the first liner, the anchor being activated using the pressure chamber.

16. The apparatus of claim **15**, wherein the anchor including a decoupling device configured to decouple the anchor from the first liner, the decoupling device being activated using the pressure chamber.

17. The apparatus of claim **14**, wherein at least a portion of the pressure chamber is formed inside a bore of the first liner.

18. The apparatus of claim **14**, wherein the work string is configured to flow fluid into the pressure chamber.

19. The apparatus of claim **14**, wherein the at least one upper sealing member is fixed to the work string.

20. The apparatus of claim **14**, further comprising a dynamic seal surrounding the at least one connector and configured to allow axial movement of the at least one connector while maintaining a seal.

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